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MINERAL RESOURCES OF OHIO

By

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INTRODUCTION

The mineral resources of Ohio consist of the common, ordinary kinds that are fitted so well to serve the general needs of man. They comprise mainly the sedimentary rocks, such as coal, clay, shale, limestone, dolomite, sandstone, conglomerate, iron ore, marl, peat, gypsum, salt, and flint. To these may be added also petroleum, natural gas, and salt brines which are associated with the stratified but deep-seated rocks. The mineral resources are conveniently distributed over the State, are present usually in large quantities, occur under favorable conditions for recovery, and have the necessary qualities for satisfactory utilization. Ohio holds sixth rank in the states in the value of its mineral resources. It is surpassed by Pennsylvania, largely through coal and cement; by Oklahoma, California, and Texas, through petroleum and natural gas; and by West Virginia through coal and natural gas.

COAL

The Moravians that made the first settlement in Ohio in 1772 at Schoenbrun knew of the presence of coal and iron ore in the Tuscarawas Valley. Its occurrence elsewhere was recorded before 1800 by soldiers, travelers, and surveyors. The first recorded use of coal in Ohio as a fuel appears to have been its utilization for the evaporation of brine in 1803 at the Jackson "salt licks." In 1810 the Sharon coal was worked in a ravine at Tallmadge and the Pittsburgh bed was mined by drifting by Bazaleel Wells at Steubenville. Mineral fuel was regularly mined and offered for sale in 1814, by Joseph Sheets at Zanesville. Coal was used at an early date by the Heatons at old Maria furnace at Niles for domestic purposes and probably at the forge. Shipments of such fuel on the Ohio River began by flatboats in 1819 and by a regular towboat, the Condor, in 1835. The main centers of production were Pomeroy, Bellaire, Martins Ferry, and Steubenville. Transportation of coal over the Ohio Canal to Cleveland for use in coaling steamboats began in 1827 from mines on "Coal Hill" near Tallmadge. A great impetus to mining came with the use of raw coal in iron making with the placing in operation in 1845 of Mary furnace at Lowellville. Coal furnaces were then built rapidly in the Youngstown, Massillon, Jackson, Ironton, Hocking Valley, and Steubenville districts. The opening of the Lake trade also increased mining in a large way. At present the industry is in an active condition in most of the fields.

Ohio is rich in fuels: coal, natural gas, bituminous shale, and peat. Coal is a rock in that it is derived in the general processes of nature along with shale, limestone, sandstone, clay, and iron ore. Bituminous coal, the kind found in Ohio, is composed of carbon in a finely divided form, of complex hydrocarbons functioning as a cement, of gums, resins, and spore cases remaining from the plant, and of clay matter constituting the main part of the ash. Such deposits were formed in flat marshy lands that were undergoing little or no change in elevation. The climate during that time was mild and the humidity constant and high. Under such conditions plant life flourished vigorously with the result that much dead material fell to the ground. Under the moist swampy conditions prevailing, the woody tissue was much altered by bacterial action, solution, etc., and finally converted to peaty material. Then through subsidence these beds of immature coal in the lowlands were buried by other sediments and finally consolidated to the hard, firm fuel that we now mine to supply our needs.

The coal-bearing rocks of Ohio have a maximum thickness of approximately 1,575 feet and extend over an area of 12,340 square miles. In a general way, such strata lie in the eastern and southeastern parts of the State east of a line drawn from Portsmouth on the Ohio River through Lancaster, Newark, Wooster, Medina, and Chardon to Youngstown, near the Pennsylvania line. The counties with important fields of coal are Columbiana, Stark, Carroll, Jefferson, Tuscarawas, Harrison, Coshocton, Belmont, Guernsey, Muskingum, Noble, Morgan, Perry, Hocking, Athens, Vinton, Meigs, Gallia, Jackson, and Lawrence. The fields are thus well distributed over a wide area. In order of importance the five leading counties are Belmont, Jefferson, Athens, Harrison, and Guernsey. The total annual production for the State is normally about 30,000,000 tons although the mean consumption is approximately 70,000,000 tons.

In Ohio the number of separate and distinct coal beds that have been named and properly correlated is fifty-three. Of these seventeen beds thicken sufficiently and lie conveniently for mining in a large way for railroad shipment; eighteen beds, somewhat thinner or less favorably located, are worked locally for household purposes; and eighteen members are too thin or too impure to be useful as a fuel supply.

The ten coal beds of most value in this State in the order of their importance are, Middle Kittanning, Pittsburgh, Upper Freeport, Lower Freeport, Pomeroy or Redstone, Meigs Creek, Clarion, Brookville, and Waynesburg. Some of the more prominent members will be considered briefly.

The stratum of most importance in Ohio is the great Middle Kittanning coal, which extends across the State from Columbiana County on

the east to Lawrence County on the south. It is worked to some extent in every county along its outcrop. Coal is usually present on the horizon, the thickness varying from 6 inches to 16 feet but ranging commonly between 2 feet 6 inches and 5 feet. The thick body of Middle Kittanning coal in Ohio is in Perry, Athens, and Hocking counties, where the deposits have been extensively mined since 1840. The member is at its best near New Straitsville, Shawnee, Buckingham, and Congo. The Middle Kittanning coal is worked in a large way also throughout the upper Muskingum, Tuscarawas, Sandy Creek, Conotton Creek, and Little Beaver Creek valleys.

The great Pittsburgh bed is confined most largely to eastern Ohio in Belmont, Jefferson, Harrison, and Monroe counties. Here the field includes an area of 850 square miles and the main breast of coal maintains a thickness of slightly more than 5 feet. Under ordinary conditions of drift mining such a stratum will produce 5,400 tons of coal per acre and 3,456,000 tons per square mile. Smaller fields are also present along Federal Creek in Morgan and Athens counties and in disconnected areas in southern Meigs and eastern Gallia counties. Although great quantities of fuel have been taken from these fields, the reserve is yet large.

The Upper Freeport or No. 7 coal is next in value as a fuel supply. The fields are somewhat scattered but those of chief importance are found in Columbiana, Carroll, Tuscarawas, Harrison, Guernsey, and Athens counties, where the bed varies from 2 to 8 feet in thickness and averages more than 4 feet.

The Pomeroy or Redstone coal in Meigs and Gallia counties; the Lower Kittanning in Lawrence, Jackson, Tuscarawas, Stark, and Columbiana; the Lower Freeport in Jefferson and Carroll; the Clarion in Lawrence, Jackson, and Vinton; the Brookville in Vinton, Holmes, and Stark; and Meigs Creek in Belmont, Noble, Washington, and Morgan, may all be relied upon to furnish large quantities of satisfactory fuel. Other beds, now largely depleted but of vast influence in the industrial development, were the Sharon, Briar Hill, or Massillon of northern Ohio and the Sharon and Quakertown of the Jackson district. They were extensively used in iron smelting.

The question may be asked, "What of the future supply?" With the information available, coal in Ohio in beds 3 feet or more in thickness is considered to be more than 14,000,000,000 tons and in beds 1 foot or more in thickness at least 50,000,000,000 tons. Little is known regarding some of the beds under deep covering. Under any consideration Ohio is thus assured of a fuel supply for many generations.

The uses of Ohio coals should be considered. Our coals belong to the class for general utility, being well fitted for all the common services

to which fuel is applied. They are adapted for general heating, steam generation, burning ceramic wares and lime, steam generation of electricity, making of artificial gas, and for many other purposes. At present Ohio coals are being carefully mined and properly cleaned for the trade. On the whole, they are sufficiently good to meet all ordinary demands of the factory and home and occur in such quantities as to satisfy the requirements for centuries to come.

CANNEL COAL

Cannel coal is a variety of bituminous coal with massive structure, compact texture, dull luster, and conchoidal fracture. It is characterized chemically by a high content of volatile matter, derived from the special enrichment of seed spores, resins, and gums. On account of such hydrocarbons, it burns with a smoky luminous flame but with a low heating value. Cannel coal is found in small bodies at many localities within the producing areas of Ohio. The four main fields, however, are found near Canfield in Mahoning County, Millersburg in Holmes, Warsaw in Coshocton, and Flint Ridge in Licking. The deposits are uncertain in extent and vary from 1 to 7 feet in thickness. These cannel coals are of interest for their early utility. They were employed to enrich charcoal for iron smelting in some of the old charcoal furnaces and in the early fifties they were distilled for kerosene for lighting purposes. Near Warsaw cannel coal was retorted for the tar products, benzine, and anthracine, for bases for the dye industry. Such fuel is now used for enriching artificial gas and for cheerful grate fires for the home.

PETROLEUM

Petroleum was really discovered in this State in 1814 through the drilling of a well for salt brine at Olive just east of Caldwell in Noble County. The yield of this well, aside from brine, was a rather large flow of natural gas and several gallons of oil per day.

The first production of petroleum on a commercial basis was in the William Rayley well drilled in 1860 at Macksburg in Washington County. Since this discovery more than 150,000 wells have been drilled in Ohio. Of these about 70 per cent have been productive of either petroleum or natural gas. The depth of drilling ranges from 100 feet or less to 7,000 feet or more. In western Ohio the granite has been reached in wells near Gibsonburg, Findlay, Tiffin, and Delaware.

Many producing sands with few or numerous pools are present in Ohio. Considered in ascending order the sands commonly recognized by

the driller are St. Peter, Trenton, Clinton, Newburg, Oriskany, Ohio shale, Berea, Weir, Squaw, Big Injun, Keener, Maxville, Maxton, First Salt, Macksburg-700-foot, Macksburg-500-foot, Second Cow Run, Macksburg-300-foot, Buell Run, First Cow Run, Peeker, Vincent, Wolf Creek, Mitchell, and Goose Run. Accumulation is dependent on many factors such as composition of rock, texture of rock, relation of rock to source material, general structure of the strata, lenticularity of beds, precise form of deposits, presence or absence of water, nature of cap rock, influence of disconformities, presence of faults, relation of overlap, etc. Only a few of the more important sands may be mentioned here.

The Trenton field of northwestern Ohio stretches in the form of a crescent from near Toledo on Lake Erie southward and then westward past Bowling Green, Findlay, and Lima to the Ohio-Indiana state line in Van Wert and Mercer counties. Pools of some importance have been opened in Lucas, Ottawa, Wood, Sandusky, Seneca, Hancock, Hardin, Allen, Auglaize, Van Wert, and Mercer counties. Some 75,000 wells have been drilled, of which about 80 per cent have produced either petroleum or natural gas, largely the former. Throughout this great field the Trenton formation in the Ordovician system is a grainy open-textured dolomite with the pay sands near the top. The dominating factors for production are (1) magnesian character of the rock and (2) sufficient structure to keep above the water. The depth of drilling ranges generally from 1,000 to 1,800 feet. The Trenton pools are now largely depleted but from 1890 to 1907 they produced more than 15,000,000 barrels annually.

In this State the Clinton sand ranks next to the Trenton in the production of petroleum but rates first by a wide margin in the yield of natural gas. The formation is a fine-grained sandstone, regional in extent, and unique in being free from water. It is of Medina age and correlates with the Whirlpool sandstone exposed at the Whirlpool in the Niagara River gorge at Niagara Falls. In Ohio the main trend of production in the Clinton sand is from West Cleveland on Lake Erie to Oak Hill in southern Jackson County. The main pools of oil are found in Hocking, Perry, Licking, Muskingum, Coshocton, Holmes, and Wayne counties. The initial yield is from 10 to 200 barrels and the common depth of drilling from 2,000 to 3,200 feet. The oil has a paraffin base and gives a good yield on distillation.

The Berea sand or Berea grit of the driller belongs in the lower portion of the Mississippian system and is one of the main beds in the group known as the "shallow sands" of southeastern Ohio. The formation outcrops along a line from the Ohio-Pennsylvania state line in Ashtabula County westward to Huron County, thence southward to the Ohio River

in Scioto County. Under deep covering in eastern Ohio the Berea formation maintains a thickness not far from 45 feet. The rock is fine in texture, argillaceous in composition, light bluish gray in color, and well cemented with bonding components. It has been the source of much production in both oil and gas. Some of the main oil pools are in Columbiana, Carroll, Medina, Jefferson, Harrison, Belmont, Monroe, Guernsey, Muskingum, Noble, Perry, Washington, and Athens counties.

Other Mississippian sands are Weir, Squaw, Big Injun, Keener, and Maxville. The Weir, Squaw, and Maxville are only locally of value but the Big Injun and Keener have given rich pools in many areas in southeastern Ohio. The Big Injun sand of the driller is correlative with the Black Hand member of the geologist. It is massive in structure, is coarse and often pebbly in texture, and ranges from 50 to 260 feet in thickness. It is water bearing and consequently production is confined to the higher parts of structures or of lenses. The Big Injun yields both oil and gas. The largest pools of oil are found in Monroe, Washington, Belmont, and Noble counties. The Keener sand, which is a part of the Vinton group in the Logan series, is a coarse-grained sandstone varying ordinarily from 25 to 35 feet in thickness. In general the pools in the Keener sand are rich, the yield high in either oil or gas, and the life of the wells long. This formation is especially prolific of oil in Monroe, Washington, and Belmont counties.

Almost any sandstone within the Pennsylvanian system may act as a reservoir for the accumulation of petroleum or natural gas. The storage of such hydrocarbons, however, is dependent upon several factors such as structure of the rocks, shape of the sand bodies, lenticularity of beds, porosity of rock, presence of salt water, etc.

The sands in the Pottsville series are, in ascending order, Maxton, First Salt, and Macksburg-700-foot. These are widely distributed and are recognized in Lawrence, Gallia, Meigs, Athens, Morgan, Noble, Washington, Monroe, Belmont, Jefferson, and Columbiana counties. In general the pools are local and the wells not large. In the Allegheny series the only sands of much importance are the Macksburg-500-foot and the Second Cow Run, which have been productive locally in southeastern Ohio from Meigs to Belmont County. The shallow sands of most importance are found in the Conemaugh series.

In Ohio the production of petroleum on a commercial basis began in the Cow Run sand at Macksburg in 1860 and on Cow Run in 1861. Since then thousands of wells have been drilled to this stratum in Washington, Morgan, Noble, Athens, and Muskingum counties. Other sands with more limited production are the Macksburg-300-foot, Buell Run, Peeker, Vincent, Wolf Creek, and Mitchell. Locally in southeastern Ohio these mem-

bers yield wells with an excellent output of high-grade oil. In the Monongahela series the only sand is the Goose Run, which correlates with the Sewickley sandstone and which is productive only on Goose Run in Washington County.

NATURAL GAS

Hildreth in his report to the Geological Survey of Ohio in 1838 records the discovery of natural gas in drilling for brines at Olive in Noble County in 1814, on Leading Creek in Meigs County in 1882, and on the Hockhocking River in Athens County in 1824. Later similar results were obtained in drilling other brine wells, and in a few places the gas was used for fuel in salt making. The intense drilling for petroleum after 1860, especially in eastern Ohio, naturally led to the discovery of natural gas in many wells, but as little use had then been found for this hydrocarbon it was considered a detriment instead of an asset. In 1865 a strong flow of gas was found in a well drilled near Walhonding at the mouth of the Kokosing River in Coshocton County. Later this was used for the manufacture of lampblack. In 1874 gas from a small pool near the mouth of California Hollow near East Liverpool was piped to dwellings and to a pottery. In a large way the commercial use of natural gas began in this State in 1884 with its discovery at Findlay in Hancock County in the Trenton dolomite at a depth of 1,140 feet. This gave an impetus to drilling throughout large areas in Ohio and soon led to much increased production. The most important of these was the discovery of the great Clinton field first at Lancaster in Fairfield County in 1887. Since that time developments have been extensive over wide areas.

In Ohio, the sands of most importance are, in ascending order, Trenton, Clinton, Newburg, Oriskany, Ohio shale, Berea, Big Injun, Keener, Second Cow Run, and First Cow Run. Others that have been of some aid in the development of the natural gas industry are Gordon, Weir, Squaw, Maxton, First Salt, Macksburg-500-foot, Macksburg-300-foot, Buell Run, Peeker, Vincent, Wolf Creek, Mitchell, and Goose Run.

The development of the great Trenton field in northwestern Ohio in 1884 was a momentous event for the commercial application of gas as a fuel in the State and for its production and distribution in a large way. The pay stratum is confined to the upper layers of the Trenton formation where this rock is a dolomite of an open, even cavernous nature and where the structure is sufficient to exclude the flood of brine. In Trenton wells the yield of gas is relatively large and the rock pressure normal for the depth. Most of the wells are between 1,100 and 1,600 feet in depth. The largest pools are in Wood, Hancock, Hardin, Auglaize, and Mercer counties and contribute supplies to towns, villages, and farm homes.

The Clinton is the great gas-bearing stratum of Ohio. The nearly continuous field stretches along an axis from near Oak Hill in southern Jackson County to Lakewood on Lake Erie in Cuyahoga County. To date the sand has been penetrated by more than 25,000 wells, some 70 per cent of which have been productive. Pools of importance are present in Jackson, Vinton, Hocking, Athens, Fairfield, Perry, Muskingum, Licking, Knox, Coshocton, Holmes, Tuscarawas, Richland, Ashland, Wayne, Stark, Medina, Summit, Lorain, and Cuyahoga counties. The Clinton sand of the driller is of Medina age and correlates with the Whirlpool sandstone of the Niagara Gorge. The depth of drilling ranges from 1,000 to 5,000 feet. The Clinton field is far from exhaustion as new pools are discovered from year to year.

The Newburg sand of the driller is really the top layers of the Niagara dolomite. The horizon is commonly marked by a large flow of brine but locally in Cuyahoga and Summit counties it yields natural gas in commercial quantities. The Oriskany formation in eastern Ohio is a true sandstone, is erratic in distribution, and is dependent on structure for accumulation. Commonly the yield is natural gas and not petroleum. The pools of most value are confined to Guernsey, Tuscarawas, Coshocton, Muskingum, Ashtabula, and Columbiana counties. The Ohio shale is of interest for the possibilities of future production through distillation and through drilling with heavy shooting. During the early fifties kerosene was distilled from the black carbonaceous shale of the Ohio formation at Buena Vista in Scioto County. The yield consists of crude oil, ammonia, tar, and excess gas. The thickness of shale is about 400 feet and the area available some 400 square miles. In northern Ohio hundreds of shallow gas wells have been completed in this formation at depths of 200 to 600 feet. The fields now active and of commercial value are in Lawrence and Gallia counties where the production is not high but the wells are long lived and have a high rock pressure. The Ohio shale underlies about one-half of the State and most assuredly is an important source for natural gas for the future.

The sands of most importance in the Mississippian system are Berea, Weir, Squaw, Big Injun, and Keener. The Berea is by far the most important of the shallow sands and is a consistent producer over a wide area in eastern and southern Ohio. Pools of some importance are found in every county from Columbiana and Mahoning on the Ohio-Pennsylvania state line to Lawrence and Gallia counties on the Ohio River. The sandstone is fine in texture, medium to massive bedded in structure, and averages about 45 feet in thickness. The only large pool in the Weir sand is near Hamden in southern Vinton and northern Jackson counties. The Squaw, Big Injun, and Keener sands in the Waverly group of rocks are

important producers mainly in eastern Ohio in Monroe, Washington, Noble, Morgan, Athens, Guernsey, and Belmont counties. In these sands production is controlled by lenticularity and structure.

Many sandstones are present in the Pennsylvanian system of rocks and under certain conditions any of these may act as reservoirs for the accumulation of natural gas or crude oil. The sands of most value are, in ascending order, Maxton, First Salt, Macksburg-700-foot, Macksburg-500-foot, Second Cow Run, Macksburg-300-foot, Buell Run, First Cow Run, Peeker, Vincent, Wolf Creek, Mitchell, and Goose Run. The First Salt sand, correlative with the Massillon or Connoquenessing sandstone, is a persistent stratum throughout eastern and southern Ohio. It is commonly 20 to 40 feet in thickness, massive in structure, and coarse in texture. This bed has produced gas over a wide area and formerly yielded brine for some of the early salt works in southern Ohio. The Second Cow Run sand, placed as the Lower Freeport member, is a prolific producer of gas in Morgan, Athens, and Meigs counties and of considerable value in Washington, Noble, and Monroe counties. The First Cow Run sand, discovered in 1861, has been a consistent producer of oil and gas since that date in Washington, Morgan, Noble, Athens, and Muskingum counties. The importance of these shallow sands may best be comprehended from the fact that the estimated number of wells drilled in Washington County alone, since 1861, is more than 10,000. Almost as many have been completed in Monroe, Noble, and Morgan counties. Further, the shallow sands of eastern and southern Ohio are available for much recovery in the future.

COAL FORMATION CLAYS

The turning of ware on the potter's wheel, one of the oldest industries known to man, was brought into the Ohio settlements through the necessity of various articles for the household. Pottery making, however, was somewhat restricted in extent as the limitation on materials was severe. It began in a small way in many places, usually in country shops worked seasonally with farming or in progressive villages with special advantages for raw materials or for trade. The first factory in Cincinnati appears to have been an earthenware pottery operated by William McFarland in 1799. This industry soon flourished also in Zanesville, Steubenville, Hillsboro, Akron, East Liverpool, Salem, and other centers. The increase in settlements and the advance of civilization created demands for other lines of ware, hence to meet those needs, yellow ware was introduced in 1840, fire brick in 1841, door and furniture knobs in 1844, sewer pipe in 1851, white ware in 1860, electrical porcelain in 1872, mosaic tiling in 1874, sanitary ware in 1888, etc.

The rise of Ohio to an eminent position in the production of ceramic wares may be attributed to an abundance of clays and shales over extensive areas, to the excellent working properties of such earths, to their fitness for a wide variety of useful wares, to the plentiful supply of fuel for manufacture and burning, to intelligent labor skilled in all phases of the work, to the varied means of transportation, railroad, boat, and truck, and to the commanding position of the State for the general markets of the country. Ohio takes first rank in the United States in the value of its clay products. Normally the annual valuation is between $40,000,000 and $60,000,000 and in peak times has reached close to $100,000,000.

Stoneware, yellow ware, Rockingham, and Majolica have been made since pioneer days from the coal formation clays of eastern and southern Ohio. The great sewer pipe regions are along the Ohio River in eastern Ohio and in the Tuscarawas Valley in the east central part. Along with sewer pipe, related products include wall coping, radial block, liner plates, flue lining, chimney tops, and special shapes. The manufacture of fireproofing has grown to a large and important industry with a wide variety of fabricated products. Conduits for underground cables, originating in Ohio in 1888, are a regular output of several factories. Refractory ware, made from high-grade flint, semi flint, and plastic clays, include fire brick, insulating brick, locomotive linings, hot-top shapes, ladle brick, stove lining, saggers, retorts, crucibles, and many related wares. The fabrication of glass pots and tanks is a specialized industry practiced at a few plants. Another intricate product for which the State has been noted since 1897 is chemical stoneware. Wide application is also made of floor, wall, decorative, quarry, and promenade tiling. This State is especially well supplied with raw materials for terra cotta and glazed building block, salt glazed and enameled brick, skintles, and paving block.

Through the local clays the ceramic industry in Ohio also advanced to wares made from kaolin, ball clay, feldspar, and flint gathered beyond our borders. China ware is produced in variety and in quality to suit almost any taste. The products range from the cheapest bargain-counter grades to the finest Belleeks. The manufacture of electrical porcelain, from the simplest to the most complex patterns, is carried on in a large way in several centers. Cooking and serving wares, both durable and artistic, are regularly produced for the trade. Gas heating porcelain is a staple product. For the pottery industry, accessories such as stilts, pins, and spurs are made in large quantities. Other wares of less note are smoking pipes, marbles, door and furniture knobs, novelties, filter mediums, and grave markers.

Some of the coal formation clays in Ohio, especially the Lawrence and Lower Kittanning, have found wide application for their bonding

properties. The main uses are for bonding refractory materials and molding sands, for refractory mortars and high temperature cements, for stopping clay at furnaces and foundries, for plastering ladles and cupolas, and for other uses in the industrial fields. The demands for raw and ground clays are steadily increasing through new uses being developed in the advance of industry.

A few of the more prominent clay strata of Ohio may be discussed briefly. The oldest member in point of geological time that has been of special service is the Sciotoville, which lies in the lower part of the Pottsville series and which has contributed since 1863 flint and semi-flint clays for a wide variety of refractory products. The main fields are in Scioto and Jackson counties but scattered deposits are also found in Vinton, Hocking, and Perry counties. The Mercer clays, of which there is quite a group, first attracted the attention of the early potter for stoneware, then later for yellow ware, Rockingham, and Majolica. These clays have a special value also for buff and gray building brick, conduits, and salt-glazed brick. The field is wide as the Mercer clays are present in a belt extending from the Ohio River in Lawrence County to the Ohio-Pennsylvania line in Mahoning County. The Tionesta and Brookville clays, closely associated and very similar in properties, have been the standard for stoneware and yellow ware for many years. These industries have been largely centered around Zanesville, Roseville, and Crooksville. These clays also enter in a large way floor and wall tile, chemical stoneware, cooking ware, face and salt-glazed building brick, and fireproofing. These strata extend with some wants across the State but the deposits most worked are in Perry, Muskingum, Tuscarawas, and Stark counties.

In Ohio, the Clarion clay found near the base of the Allegheny series is of value in only two fields, one in the southern part of the State in Lawrence, Gallia, Jackson, Vinton, and Hocking counties, and the other in the eastern part in Columbiana and Jefferson counties. Locally this clay assumes qualities fitting it especially for refractory ware, sewer pipe, terra cotta, quarry tile, ladle brick, and building brick. The great clay horizon of Ohio, and in fact in the United States, is that lying between the Vanport limestone and the Lower Kittanning coal, an interval usually more than 20 feet in height and largely plastic clay of excellent quality. The interval really holds two clay beds, the Lawrence, the one of most worth, and the Lower Kittanning, lying directly or closely above. In a way, this horizon may be traced across the State by a line of ceramic plants. In Lawrence and Jackson counties it yields one of the finest terra cotta clays in the United States; in the Tuscarawas Valley and along the Ohio River in southeastern Ohio it has become the standard for sewer pipe, flue lining, wall coping, liner plates, etc.; in the Strasburg district of

Tuscarawas and Carroll counties it provides flint clay for refractory ware, and at other places is satisfactorily used for building brick, fireproofing, conduits, stoneware, and bonding clay. Locally in the Oak Hill district the Oak Hill clay assumes a flinty texture and is the basis for an extensive fire brick industry.

The coal formation clays of Ohio have thus played an important role in the development of the State. They have furnished the raw material for a great list of wares for domestic purposes, the building trades, sanitation, the iron and steel industries, artistic effects, and many other uses. Such earths have been responsible for the addition of much wealth and for many steps in the general progress of civilization.

SHALE

Shale may be defined as a silt stone or as a fine-grained argillaceous rock derived from the finer products of decay of upland areas, sorted by running water as to grain size, and deposited by the agencies of water. Many shales are thus so prepared by nature with respect to textural properties, plastic qualities, fluxing components, etc., as to be especially fitted for some of the more useful wares. In general, the shales burn to a pleasing red color and to a dense durable body; in fact they often yield products unexcelled for quality.

Shales were utilized to a small extent by the early settlers for earthen pottery, building brick, and door and furniture knobs. They became intensely important, however, when used at Akron in 1851 for the production of the first sewer pipe in the United States. This event marked a turning point in the ceramic industries of Ohio and eventually led to ascendency in that field. About 1865, shale was employed at Cleveland for dry-press building brick and in 1885 it was used at Malvern for paving block. For the latter purpose this material has remained standard as the ware has the density and toughness demanded. By far the bulk of the high-grade building brick is produced from shale. Such plants are well distributed over the eastern half of Ohio and yield ware attractive in color, resistant to weathering, and low in cost. Most of the structural hollow wares used in building and of the earthen tile used for roofs are fabricated from shale. It is a common material also for drain tile, quarry and promenade tile, floor, wall, and decorative tiling, and foundation block.

Shale is a common rock throughout the eastern half of Ohio. Strata of this character range in age from the Devonian to the Permian systems. The deposits of most worth, however, are confined to the upper part of the Mississippian and the lower half of the Pennsylvanian systems.

Fortunately for Ohio such deposits in many places have the physical and chemical properties necessary for satisfactory ceramic products. A few of the shale formations deserve attention.

In Ohio the rocks of the Mississippian system are largely shales or sandstones. Such deposits are found in a wide area extending from the Ohio River in Scioto County northward to Lake Erie in Erie and Lorain counties, thence eastward to the Ohio-Pennsylvania line in Ashtabula and Trumbull counties. The main activities in production are near Portsmouth, Hanover, Wooster, and Cleveland. One of the prominent shales in the coal formations is that above the Putnam Hill limestone in the basal portion of the Allegheny series. This material has special qualities and has been utilized in a large way at New Lexington, Roseville, Zanesville, Sugar Creek, Stone Creek, Port Washington, and Canton. A shale of much merit is that above the Middle Kittanning coal, which is used for a wide range of products in Perry, Muskingum, Coshocton, Tuscarawas, and Stark counties. The wares include building brick, paving block, sewer pipe, drain tile, building block, and fireproofing. A few deposits in the lower part of the Conemaugh series find employment for high-grade face brick and building block. On the whole, the shales of Ohio are an asset of great value and their worth bids fair to increase.

ALLUVIUMS, RESIDUALS, AND GLACIAL CLAYS

Fortunately some of the pioneers that entered Ohio were familiar with the nature of surface clays and with the manufacture of such earths into wares needed for the advance of civilization into the wilderness. In the early days the common practice was for the brickmakers to travel from place to place, molding, drying, and burning bricks for homes, schools, churches, court houses, and factories. Historical records show that brick were made upon the ground and burned by men experienced in that line of industry for the chimneys of Campus Martius built at Marietta in 1788-91. The brick-making industry spread rapidly throughout Ohio and soon brick was a common building material in all parts of the State.

Alluviums are fine-grained clays left along stream courses by flood waters. They are thus well prepared by the processes of nature and suitably fitted for certain ceramic products. A residual, as the name implies, is the residue of decay. Where the normal material is shale, the resulting residual is a clay often of value for ceramic purposes. The great glaciers left much material over Ohio. Where the deposits are largely of fine material and well weathered, the few feet near the surface assumes workable properties.

In general, the alluviums, glacial clays, and residuals are used in a large way for common products, such as common brick, drain tile, and

back-up blocks. They are the chief source of materials for flower pots, made in quantity at many places. Such earths enter also, but to a less degree, into some of the finer wares, such as floor and wall tile, art pottery, cooking and serving ware, Majolica, and roofing tile.

LIMESTONE

The consolidated rocks throughout the western half of Ohio are limestones, dolomites, and calcareous shales. Thinner, more local, and less valuable deposits are present throughout the coal fields in the eastern and southeastern parts of the State.

The calcium-bearing rocks of Ohio may be divided into four kinds:

Limestone of marine origin
Dolomite of marine origin
Limestone of fresh water origin
Marl, an unconsolidated limestone of recent fresh-water origin

The limestones are composed mainly of calcium carbonate with a small content of magnesium carbonate and with a variable addition of sand, iron oxides, clay matter, pyrite, and incidental impurities. Common limestone with an increase in magnesium carbonate passes to dolomite and with an increase in argillaceous matter to calcareous shale. Marine limestone was laid down in parts of the sea where the water was moderately warm, fairly shallow, and comparatively clear. The calcium carbonate, the chief constituent, was derived from the soluble carbonates of the sea water by the action of plant and animal life, which either extracted the solid matter for their own shells and frame work or utilized the carbon dioxide, thereby precipitating the limy portions to be consolidated to firm rock. On this account some limestones contain much evidence of the marine life as fossil shells, corals, etc., whereas others are composed almost entirely of finely divided but compact matter.

The prominent high-calcium limestones of Ohio are the Brassfield, Maxville, Vanport, and locally the Columbus. The Brassfield member, belonging to the basal portion of the Silurian system, outcrops in Preble, Montgomery, Miami, Clark, Greene, Clinton, Highland, and Adams counties. The deposits are from 20 to 60 feet in thickness and average around 30 feet. The stone is compact, crystalline, and often ferruginous. The Columbus limestone, or the old Corniferous of the early surveys, outcrops in a broad belt from 10 to 25 miles in width and nearly 150 miles in length, from southern Pickaway County on the south to the tip of the Marblehead Peninsula in Ottawa County. A second field is a crescent-shaped area in northwestern Ohio on the flank of the Cincinnati arch. In general, the Columbus is 40 to 60 feet in thickness, massive in bedding, somewhat earthy in appearance, and light gray to buff in color. The com-

position of the stone varies from a rather pure limestone to a calciferous dolomite. Through crustal movements and erosion, the Maxville limestone of Mississippian age was removed from much of the area over which it is due in eastern Ohio. Therefore, the deposits remaining are local and scattered. The areas of most value along the outcrop are found in Lawrence, Jackson, Perry, and Muskingum counties. It is also present under deep covering in Monroe, Washington, and Belmont counties. This stone is dense, light colored, and relatively pure. The Vanport limestone belongs in the Allegheny series of the Pennsylvanian system. It outcrops prominently in southern Ohio in Lawrence, Scioto, Jackson, Gallia, and Vinton counties. The stratum varies from 2 to 20 feet in thickness.

These limestones are of special utility for Portland cement, steel and blast furnace flux, water softening, agricultural lime, hydrated lime, glass making, chemical industries, ceramic glazes, paint pigment, and soap and glycerine manufacture. These strata with others less pure are used for rock wool, railroad ballast, road metal, concrete aggregate, and building and heavy masonry stone.

The fresh-water limestones are found in the coal-bearing formations of southeastern Ohio and extend from Columbiana County on the east to Lawrence on the south. These limestones are generally lenticular or bouldery in form, vary greatly in thickness, are somewhat uncertain in extent, and are commonly much interbedded with calcareous shale. They contain some fossils, low in order and small in size. Such limestones were formed in swamps where bacteria and other low forms of plant life played the important part of causing direct precipitation of the calcium carbonate. In Ohio the fresh-water limestones are or have been of service for natural rock cement, blast furnace flux, hydrated lime, concrete aggregate, road metal, and agricultural lime.

DOLOMITE

Dolomite is one of the common rocks appearing at the surface in the western half of Ohio. Such material is available in large areas, is favorably placed for quarrying, has the massive formation necessary for economic working, and has contributed much to the wealth of the State. The deposits of most importance are confined to the Silurian and lower Devonian systems. The combined thickness of such strata in western Ohio ranges from 100 to 600 feet, thus assuring an inexhaustible supply.

Dolomites are rocks composed of one part calcium carbonate, one part magnesium carbonate, and of more or less shaly and siliceous matter from the land surface. They were formed much the same as limestones except that the chemical processes went farther, allowing magnesium from

the sea water to substitute for one-half of the calcium of the normal carbonate. The dolomites are usually sugary in texture, are light gray to drab in color, and have poorly preserved fossil remains. A few of the great beds of very pure dolomite in western Ohio will be considered.

The Cedarville, Peebles, or Guelph dolomite of the Niagara series is certainly one of the finest rocks of this character in America. The largest field is in the southwestern part of Ohio in Adams, Highland, Clinton, Greene, Fayette, Clark, Champaign, Logan, Montgomery, Miami, Shelby, Auglaize, Preble, Darke, Mercer, and Van Wert counties. The second field is in the north central part in Marion, Hardin, Wyandot, Hancock, Seneca, Wood, Sandusky, Ottawa, and Lucas counties. The thickness of the formation varies from 30 to 80 feet but averages nearly 60 feet. In general, this stone is highly crystalline, has a sugary open texture, and on weathering assumes a honey-comb effect. Usually the member is massive in structure, the entire formation often appearing as a single bed. The Greenfield formation is best exposed in southern Ohio, the type locality being at Greenfield in Highland County. In the northern part of the State, this formation appears also on the flanks of the Cincinnati arch. The deposits range from 75 to 100 feet or more in thickness. The stone, close to a true dolomite in composition, is fine in grain, light drab to brownish gray in color, and thin to medium in bedding. The best development of the Lucas dolomite in Ohio is in the northwestern part in Lucas, Wood, and Henry counties. The sections exposed are from 30 to 75 feet in thickness but the maximum measurement is more than 140 feet.

In Ohio, the important use of dolomites, especially the Cedarville, is for lime burning. The product is rated one of the very best in the United States for mortars and plasters and on this account has a wide market. These formations are also worked extensively for railroad ballast, road metal, concrete aggregate, flux in steel and blast furnaces and in cupolas, dolomite refractories and clinkers, carbon dioxide for dry ice, ingredient of glass wool, many chemical purposes, agricultural lime, building stone, and heavy masonry work.

MARL AND TUFA ROCK

In this State deposits of marl are confined to the area north of the terminal moraine of the Wisconsin drift. Such material occurs locally in the swamps and marshes on this old glaciated surface and is usually associated with peat. The deposits are uncertain in thickness, in extent, and in quality of the material.

Marls are the direct result of precipitation of soluble calcium carbonate by aquatic plants and small mollusca in swampy waters. The common kind is fine and powdery, the direct precipitate, whereas the so-called

shell marl also contains the shells, largely of fresh-water snails. On analysis marls vary much, depending on the amount of clay or peat admixed with the calcareous matter. The better grades vary from 85 to 98 per cent calcium carbonate. Marls have a true value for Portland cement, agricultural work, water softening, chemical uses, etc. The main deposits are in central, northern, and west central parts of the State. The calcareous tufa rock, used so extensively in decorative landscaping, is a porous spongy stone, resulting from the precipitation of calcium carbonate around vegetable matter from the waters of large springs of deep-seated origin.

SANDSTONES AND CONGLOMERATES

The pioneer settlers, mainly through necessity, first turned the local sandstones in the eastern half of the State to profitable account in building homes, mills, factories, dams, bridges, canal locks, furnaces, cupolas, public buildings, etc., as a progressive step in the development of the State. Such materials were widely distributed over the area, had outcrop exposures favorable for quarrying, were readily fashioned by the mason into desired forms, and, in general, were pleasing to the eye or gave appeal to the sense of durability. The sandstones of Ohio have a wide range in color, texture, and composition. The color range varies from nearly white through gray, buff, yellow, brown, and pink, to dark red. In some the shades are pleasing and permanent. In grain size the change is from very fine and silty to coarse or even pebbly, the latter being conglomerates. Through the effects of various bonding components, such as silica minerals, iron oxides, basic carbonates, etc., the structure of the sandstones varies from a dense hard mass to an open friable rock barely able to hold together. In general, the building stones on exposure become more firmly bonded through the fixing of the cements.

The sandstones and conglomerates of Ohio have been very useful in many other roles than for building purposes. Some of the most important of these may be mentioned. The iron industry in this State began on a sandstone lining. Such material continued as the standard lining for charcoal furnaces from the building of Hopewell furnace on Yellow Creek in 1804 to the blowing out of Jefferson near Oak Hill in December, 1916. These sandstone linings served the purpose very well as the material was moderately refractory, was fairly resistant to abrasion, was quite effective in meeting the acidity of the slag, and was so changed by heat—the quartz grains changing to tridymite as to become impervious to gas penetration. Material suitable for such work was easily available, usually quarried near by, and was placed in the walls of the stack by the masons at the works. The hearths of the early forges and cupolas were also made of sandstone.

Later ganister or the hard clay-bonded sandstones of southern Ohio found extensive use for lining Bessemer converters and soaking pits.

Next the Sharon conglomerate of northeastern Ohio became of importance for refractory purposes. In the United States the silica brick industry originated at Akron in the old Diamond Brick Works of J. Park Alexander. He took out patents in 1872 for the manufacture of silica brick from quartz aggregate bonded with lime. At this time such ware was extensively used for linings of puddling furnaces at rolling mills. At present the silica brick industry is well established, with plants at Niles, Portsmouth, Oak Hill, and Jackson. The ware is of special value for roofs of basic and acid hearth steel furnaces, for regenerators, for coke ovens, and for many other metallurgical purposes. Ohio is advantageously supplied with inexhaustible amounts of both quartz aggregate and lime, the raw materials for the industry.

Some of the more prominent sandstone or conglomerate members in Ohio are worthy of mention:

The Berea sandstone of Mississippian age is one of the best known rocks of this class in Ohio as it is important along the outcrop as a source of building stones and abrasives and under deep covering as a storage reservoir for petroleum, natural gas, and salt brine. The formation expands from 5 to 225 feet in thickness but averages about 45 feet. The typical stone is massive in structure, medium fine in grain size, rather open in texture, and light gray to slight buff in color. It quarries with good economy and works well either by chipping or sawing. The outcrop of the Berea sandstone is marked in a general way by small or large quarries in Trumbull, Ashtabula, Geauga, Lake, Cuyahoga, Lorain, Erie, Huron, Crawford, Morrow, Delaware, Franklin, Pickaway, Ross, Pike, Scioto, and Adams counties. The most prominent quarries are confined to northern Ohio in Lorain, Cuyahoga, and Erie counties. The uses to which the Berea sandstone is put are many, principal among them being building stone, curbing, flagging, and riprap. It is the chief source in the United States for grindstones, whetstones, and related rubbing implements, Of recent years a new and important use is sawed stone for refractory linings of cupolas, in replacement of silica brick. Such blocks are cheap, stand up well against heat and slag, and are easy to replace.

The Buena Vista member of the Mississippian system deserves attention as it has been for a hundred and thirty years or more a source of supply for building stone for a variety of purposes, ranging from heavy masonry to sawed stone for the finer purposes. The quality is good and the color attractive. Although the formation outcrops across the State from Scioto County on the Ohio River to Trumbull County on the Ohio-

Pennsylvania line, the areas of most importance are in Scioto and Pike counties.

Another important member of the Mississippian system is the Black Hand, which forms conspicuous deposits in Hocking, Fairfield, Licking, Knox, and Richland counties. It is of massive formation, often one great ledge from 50 to 300 feet in thickness. The stone changes in texture from a coarse-grained sandstone to a rather pebbly conglomerate and in color from nearly white to shades of gray, buff, pink, or brown. The Black Hand member is of value for many economic purposes and for the picturesque and attractive scenery presented along the outcrop. It furnishes much attractive building stone, usually in the buff and pink shades. Through crushing, followed by screening, air separation, or washing, it finds a good market for such purposes as molding sand, mortar sand, sand finish of plastering, sand for sand blasting, engine sand, glass sand, etc. To the driller for oil and gas the Black Hand sandstone is known as the Big Injun sand, productive in several fields in eastern Ohio. In the Pomeroy district of Meigs County, this stratum is one of the important sources for brines for the salt industry, yielding salt, calcium chloride, and especially bromine.

The Sharon conglomerate at the base of the Pennsylvanian system is one of the very interesting deposits of Ohio for its geological history, for its physiography and scenery, and for the many uses to which it is applied. The rock varies in composition from a medium-grained sandstone to a coarse pebbly conglomerate, very loosely cemented. The deposits always occupy broad deep depressions cut in the older Mississippian floor, are thus erratic in distribution, and vary from 10 to 250 feet in thickness. The pebbles are vein quartz. They were derived from the Canadian fields to the north and after long cycles of weathering and transportation finally came to rest in great beds in Ohio. The Sharon conglomerate is well developed locally in Scioto, Jackson, Pike, Perry, Stark, Summit, Portage, and Trumbull counties. The material is of importance for silica brick, aggregate for filtration plants, sized aggregate for tarred roofing, sand blasting, road building, stucco work, and concrete aggregate. Some glass and foundry sands are also produced from selected material.

The Massillon sandstone in the Pottsville series extends with some wants across the State from Youngstown in Mahoning County to Scioto-ville on the Ohio River in Scioto County. The member is usually massive in character, from 20 to 50 feet in thickness, and commonly rather coarse in texture. The color varies from light gray through buff and pink to brown. This member is outstanding for a few purposes. Through washing and treating with acid it yields glass sands of the highest purity, through crushing and sizing it is especially fitted for foundry work, and through

selection and sawing it produces a variegated building stone of superb quality.

The Homewood, Clarion, Lower Freeport, Upper Freeport, Buffalo, Cow Run, Connellsville, Bellaire, Waynesburg, Marietta, and Hundred sandstones are locally important.

Ohio is one of the large producers of pulp stones used in the paper industry in reducing the treated wood to pulp. These stones are shipped throughout the United States and to many foreign countries. The main quarries are in Columbiana, Jefferson, and Washington counties. The sandstones in the Marietta district are widely employed for shaping into large grindstones for edging tools, burnishing, and similar uses.

SAND AND GRAVEL

The sand and gravel deposits in Ohio are largely the work, directly or indirectly, of the great glaciers that in Pleistocene time extended over about three-fifths of the area and contributed materials along the main drainage ways in the remaining portion. The best deposits, regarding sorting, sizing, etc., are the outwash beds along streams, such as the Miami, Scioto, Hocking, Muskingum, and Tuscarawas rivers. Outwash aprons along morainic fronts and kames and eskers within the glaciated area also provide much good material. On this account both sand and gravel are widely distributed. The sand is employed mainly for mortars, plasters, concrete, and filters; and the gravel has extensive use for railroad ballast, highway facings, and concrete.

BRINES

Brines for the manufacture of salt have been of great importance to Ohio since the industry was initiated in 1797 by the white settlers at Jackson. In a crude way, however, the brines here issuing from the Sharon conglomerate along Salt Creek had been worked for hundreds of years by the aborigines who evaporated the weak solutions by the heat of the sun or by boiling with wood fires. Soon after 1800 the industry gained headway in Muskingum, Columbiana, Morgan, Athens, Tuscarawas, Gallia, Meigs, and Guernsey counties.

Such brines are considered to be the connate or fossil sea water held in the interstices of the rock and left there through the process of deposition of the rock mass in the sea. Later such salt solutions were greatly enriched and considerably modified by operations of nature not well understood. The concentration of the brines varies from 37 grams per 1,000,

that of sea water, to 280 grams per 1,000, that of some salines from the deep-seated rocks. In general, the deeper the brine the higher the concentration. Good commercial brines are now pumped from depths ranging from 1,000 to 3,000 feet.

Commercial brines are found at many horizons ranging in age from Cambrian to Conemaugh. They may occur in limestone, dolomite, sandstone, or conglomerate, the containing rock only slightly affecting the quality of the solution. A few of the major horizons may be mentioned.

The deep St. Peter or "Blue Lick" brine of Ordovician age is considerably below normal in salinity but is commonly highly charged with hydrogen sulphide. The Second Water in the "Big Lime," which is placed near the top of the Niagara dolomite, is one of the most important. This brine is found over a wide area, has a large flow, is high in concentration, and is especially rich in such components as magnesium, calcium, and bromine. It is well balanced for general chemical work. The First Water in the "Big Lime," which is at the horizon of the Oriskany sand, is high in concentration and rich in magnesium, but is somewhat restricted in flow and in distribution. It is especially fitted for the extraction of magnesium and bromine. The brine in the well-known Berea sand is wide spread in eastern and southern Ohio and formerly was used at many places for making common salt. The flow in the Big Injun sand of southeastern Ohio is large and the concentration moderate. It is used in the Pomeroy district, where the yield is salt, bromine, and calcium chloride.

Directly or indirectly, brines such as the First and Second Water in the "Big Lime" are especially valuable for the chemical industry in the preparation of several hundred compounds for the market. These include medicines, dyes, insecticides, flavors, industrial chemicals, metals and alloys, and various others. A few of the prominent compounds are listed: ammonium bromide, bromoform, calcium bromide, potassium bromide, chloroform, epsom salt, phenol, methyl salicylate, salol, tetrachlorethylene, trichloracetic acid, coumarin, methyl anthranilate, acetic anhydride, acetylene tetrachloride, aniline oil, carbon bisulphide, carbon tetrachloride, magnesium chloride, mining salts, monochlorbenzene, sodium sulphide, sulphur chloride, magnesium, Dowmetal, ciba dyes, indigo, calcium arsenate, lime sulphur, paradichlor benzene, and many others.

ROCK SALT

In the northeastern part of Ohio, thick beds of rock salt occur far down in the consolidated rocks in an area of over 7,000 square miles east and north of a line drawn roughly from Lorain on Lake Erie, through Wooster, New Philadelphia, and Freeport, to Bellaire on the Ohio River.

Through dip and expansion these beds descend about 65 feet per mile to the southeast. On this account the position of such beds below the surface is approximately 1,850 feet at Cleveland, 2,200 feet at Painesville, 2,600 feet at Rittman, 4,500 feet at Kensington, 4,700 feet at Freeport, and 6,400 feet at Bellaire. The salt beds belong in the Salina formation, one of the upper divisions of the Silurian system. The salt is always more or less interstratified with dolomite and shale and ordinarily makes up less than half of the mass. The thickness of this group of strata, salt, dolomite, and shale, ranges from 100 to 500 feet or more. Single layers of salt locally become massive, 50 to 80 feet occasionally being reported.

The origin of deposits of rock salt is of much interest. Such beds appear to be derived simply from the concentration of sea water to a density favorable for the crystallization and the deposition of salt grains. The energy utilized is the heat of the natural agency, the sun. The evaporation of the solution took place in an arm of the sea, as a bay or lagoon, which had but little fresh water entering it but which had only a shallow narrow channel connecting it with the sea. Such an arrangement eliminated free circulation into the enclosed body but allowed a slight filtering of sea water through the restricted opening to replace that lost by evaporation. The salinity of the water thus increased until deposition of salt took place.

As depth is one of the controlling factors of utilization, the deposits now worked lie toward the western margin of the field, where the formation is from 1,600 to 3,000 feet in depth. The method of attack is to penetrate the salt strata by the standard tools of the oil driller in a number of rather closely spaced holes. Fresh water is then pumped into the wells and allowed to stand for some time after which the brine, near saturation, is lifted by pumps and forced to the works. Through repetition of this procedure, channels and cavities are dissolved in the salt layers and eventually a subterranean circulation is established from one well to another some distance away. The brines formed in this way are highly charged with salts and are thus economical for evaporation.

The main compounds in such brine are sodium chloride, calcium sulphate, calcium chloride, potassium chloride, magnesium chloride, strontium chloride, magnesium bromide. Various other salts and some gases in small quantities are also held in solution.

During the early periods of the industry such brines were attractive simply for the salt or sodium chloride useful for general domestic purposes and for meat packing. Other leading products now marketed are soda ash, sal soda, caustic soda, bicarbonate of soda, special sodas, special alkalies, sodium sulphate, calcium chloride, bromine, chlorine, and hydrochloric acid.

GYPSUM

Gypsum, or the mineral calcium sulphate, was formed where a part of the sea was so detached that evaporation produced precipitation of the sulphate salt. Normally Ohio produces annually about 500,000 tons of gypsum, which when prepared has a market value approximating $5,000,000. The area where gypsum is found in this State is not large. The commercial deposits are confined to that portion of Ottawa County lying between Lake Erie and Sandusky Bay. The rock is mined by stripping and by drifting and is then graded, crushed and calcined for the plaster-of-Paris of commerce. The product is used extensively for fireproofing, wall board, pottery molds, stuccos, white coat of plaster, statuary, crayons, retarder for Portland cement, fertilizer base, and many other purposes.

IRON ORES

The iron ores of Ohio are of small economic value at present but in the pioneer days they were important factors in the development of the settlements and adjacent country and later they aided greatly in establishing trade throughout the Middle West. In this State iron making began in old Hopewell furnace on Yellow Creek, near Poland, Mahoning County. This small stack was built by Daniel Heaton in 1804, was operated by water power, and ran on native ores and charcoal from the near-by forests. Statistics show that 222 separate and distinct stacks have been built, largely in the eastern half of the area. Of these, 85 were charcoal furnaces run on native ores, 60 were coal furnaces operating on native with some Lake ores, and 77 were modern stacks using coke for fuel and Lake ores for the ferruginous part of the burden. The main centers were Hanging Rock in southern Ohio, the Hocking Valley in the central part, the Youngstown district near the eastern line, and the Cleveland district on Lake Erie.

The industry began on native ores. The product was a soft foundry iron very suitable for a wide variety of castings and for forging into bar iron. The importance of one of these early furnaces to the area is best shown by the products advertised, for example, by Arcole furnace in 1831; "The proprietors are now prepared to furnish dealers with 'cast iron' in all its various forms. Comprised in the apartment of stove patterns are James' and Wilson's cooking stoves, Camboos, Hall, 7 & 10 plate, Franklin, coal and box stoves, of every size and form. Also every description of 'hollow ware,' comprehending in the assortment three sizes of cauldrons; 6, 8, 10, 12, 18, 24, 30, 40, 50, and 70 pound kettles; 3 sizes tea kettles; 7 sizes pots; 3 sizes bake ovens; 6 sizes spiders; 2 sizes portable furnaces; 3 sizes griddles; basins, gridirons, stew pots, and Spanish pots. Also

5 sizes fire dogs; 60, 90, 110, 120 gallon potash kettles, mill irons, Fuller's irons, plough irons, gudgeons, wagon boxes, fanning-mill irons, etc., etc. All kinds of heavy castings, of one, two, or three tons weight. They are also prepared to cast and bore heavy cannon and small ordnance of any required calibre and steam engine cylinders from 6 to 50 inches in diameter."

The ores for smelting were of several kinds. The main ones were siderite and limonite ores from the coal formations, blackband ores found with the coal beds, limonite ores resulting from the decay of fresh water limestones, nodular ore from stream deposits, bog ore from the marshes of northern Ohio, and limonite ore from pockets along disconformities of limestone strata in south central Ohio. The deposits of most worth were the Ferriferous ore associated with the Vanport limestone, the Big Red Block ore lying on the Upper Mercer limestone, the blackband ore occurring with the Sharon and Upper Freeport coals, and the Shawnee ore from the outcrop of the Upper Freeport limestone.

At present practically no native ores are being used for metallurgical purposes. The demands are confined to calcined spongy blackband for extraction of sulphur from organic oils and fats, for siderite for bonding emery wheels and for CO_2 in the chemical industry, and for soft limonite for paint pigments. Our native ores, however, will come back for metallurgical use, more for their content of manganese and phosphorus and possible vanadium than for their iron content. Used alone some of these ores yield iron with 6 to 12 per cent metallic phosphorus and others with 3 to 6 per cent manganese.

PEAT

Aside from its fuel value, peat should be considered for its other useful properties. It is found locally in the swamps and marshes throughout much of the glaciated part of Ohio. Combined areas carefully tested include some 150,000 acres or 235 square miles. The deposits vary from 1 to 30 feet in thickness. Peat is now used extensively for humidity control in greenhouses, for producing acid soils in rock and other gardens, for humidity and mineral retention base of fertilizers, and for filler for packing.

FLINT

While only of moderate service at the present time, the flints of Ohio were formerly a valuable contribution to the needs of man. Flint provided the aborigines with a material that they could fashion to implements such as arrows, knives, skinners, and drills, all essential in their battle for

life and ascendancy. Our own pioneers next used the flints for buhr-stones for grinding grain, a service not yet wholly replaced in many areas. To a less extent stones from such material were used to grind paint pigments and to crush tan bark for the tanning industry. At the present time flint is used for the smelting of metallic silicon in the electric furnace, for sand blast abrasives, for preparing sheet metal for enamels and for etching glass, and for silica flour for paint pigments and foundry uses. The largest deposits of flint of high purity are those on Flint Ridge in Licking and Muskingum counties, where the stratum is persistent over several square miles and frequently exceeds 6 feet in thickness. Other deposits of less value are found in Coshocton, Perry, Hocking, and Vinton counties.

MOLDING SANDS

Molding sands are the fine-grained siliceous sands bonded with clay matter and iron oxides and used in the metal industries for making molds for castings. Such deposits are well scattered over Ohio but are most abundant in the eastern half. Some are of glacial origin; others are alluvials laid down along streams; a number are only residuals from the natural decay of stratified sandstones; and a few are wind-blown loess. The regions most productive are Gallia, Muskingum, Perry, Jackson, and Tuscarawas counties. Such sands are marketed for the steel, cast iron, aluminum, brass, bronze, and other allied industries.

FULLER'S EARTH

Fuller's earth may be defined as any clay-like earth which when used as a filter or contact medium has the property of extracting coloring matter from liquids of vegetable or animal origin, such as soap fats, cotton-seed oil, kerosene, etc. The phenomenon seems to be simple absorption. Under such an interpretation the Minford silt of southern Ohio falls within this class as it is especially effective in clarifying petroleum and its various products. A few of the fine-textured alluvial and glacial clays are also active in decolorizing certain liquids. Small quantities of such materials are marketed for this purpose.

OIL SHALE

The first kerosene used in Ohio was produced through distillation in the early fifties, from the black shale of the Ohio formation at Buena Vista on the Ohio River in Adams County. This shale was similar to that so treated in Scotland, the source from which the practice was copied. The upper and lower portions of the thick Ohio formation is a brown to black

fissile shale high in carbonaceous matter, the carbon being held largely in the form of the paraffin base, CnH_2n_2. On distillation the yield by the crude methods then practiced was from 5 to 8 gallons per ton. The product, although low grade, was used for lighting purposes in the local areas. The distillation of cannel coal for kerosene was also practiced on Flint Ridge in Licking County, near Warsaw in Coshocton, and at Canfield in Mahoning. The discovery of natural oil, in 1859, by Drake, on Oil Run, Pennsylvania, soon caused the abandonment of what would otherwise have developed into a large industry.

Far in the future when natural oils are exhausted the shales may again be worked by distillation. This State contains immense quantities of such low-grade carbonaceous material. The Ohio formation outcrops in a belt extending from the Ohio River in Adams County to Lake Erie in Lorain; thence it extends eastward south of the Lake to the Ohio-Pennsylvania line in Ashtabula and Trumbull counties. The formation varies from 300 to 1,000 feet or more in thickness and usually carries from 300 to 500 feet of the black and brown shale suitable for refining. On distillation the yield is crude oil, paraffin, excess gas, ammonia liquor, and tar, all useful and valuable products. The spent shale, with slight modification, may be utilized for common ceramic products. This shale should be considered a mineral resource, but certainly more for the future than the present.

BITUMEN

Bitumen, as the higher paraffin of the formula CnH_2n_2, if of common occurrence in small amounts, especially in the dolomites, limestones, and calcareous shales of western Ohio. The so-called asphalt rock in this State is only a dolomite or a limestone impregnated with this material. The area of most importance is in Highland County where the rock represents that in an old oil pool, which by uplift and erosion was brought to the surface. Such rock containing about 2 per cent paraffin is crushed, sized, and graded for road facings.

MINERALS

The true minerals, such as celestite, fluorspar, sphalerite, barite, galena, and calcite, are present with some frequency but in small quantities in the limestones and dolomites of the western half of Ohio. They occur usually as disseminated grains or as the filling of fissures and small cavities, are relatively pure, and are coarsely crystalline in the usual forms. Celestite is found mainly in the quarries in the Toledo district and on the islands in Lake Erie. Fluorspar and barite are commonly associated minerals.

Sphalerite is most abundant in the Greenfield dolomite in the vicinity of Greenfield, where it occurs as scattered nodules throughout the mass. Calcite is a common filling of fissures and cavities throughout much of the limestone area. Galena is uncommon except as small crystals in the cavities of fossils. None of these minerals has been marketed in a regular way, but some of them have been employed for special purposes.

PHOSPHATE ROCK

No large deposits of rock coming strictly under this class are present in Ohio. Materials of a phosphatic nature, however, are found among the iron ores and the limestones. The deposits of this kind of most worth are those of the Hamden ore in southern Vinton and northern Jackson counties. This ore, dried, contains on the average 33.09 per cent metallic iron, 4.78 per cent phosphorus, and 0.85 per cent manganese, and has special value in the metallurgical field. The "bone bed" at the top of the Columbus limestone, seldom more than a few inches in thickness, is made up largely of fish teeth and therefore is rich in calcium phosphate. The component is used in ground limestone for fertilizers and in flux stone for blast and steel furnaces.

PYRITE

Pyrite or its isometric form, marcasite, is a common, in fact too common, mineral present in an impure form in many of the coals and organic shales of Ohio. The mineral is the disulphide of iron, FeS_2. It was deposited largely with the original sediments in the form of grains, plates, or nodules. Slightly reducing conditions are necessary for formation. In some cases additional growth occurred around the original deposits through sulphur materials carried in by circulating ground waters. Pyrite is used for the production of sulphuric acid. In general, the manufacturers and largest users are the chemical and fertilizer industries. However, the acid finds application in many fields.

In Ohio, pyrite has been produced in a desultory way for the acid trade for many years. Such material is gathered almost entirely from the refuse piles at coal mines, mainly in the east central and eastern parts of the State. The chief supply comes from the Lower and Middle Kittanning coals of the Hocking Valley and Tuscarawas Valley fields, from the Pittsburgh coal in the Belmont field, and from the Redstone coal in the Pomeroy field. The supply is large but the material grades low.

Formerly copperas was made at Steubenville and Cleveland by roasting the native pyrite gathered from the coal fields near by. Copperas is used as a mordant in dyeing cotton and woolen cloth; in making bright

iron oxides, Venetian red, Spanish brown, etc., by conversion, for painters' colors; in paper mills, bleacheries, plate glass works, and chemical manufacturing establishments; in the precipitation of gold in leaching works; and to a slight extent in medicine.

SILICIFIED WOOD

Silicified wood is present in some abundance in local areas within the coal fields of Ohio. Such material occurs most frequently in the soft drab or red shales of the Conemaugh series, lying between the Ames limestone and the Pittsburgh coal. However, stream beds are the places for gathering a supply. Such wood is most conspicuous near the head of Middle Branch of Shade Creek in Athens County, along the upper courses of Federal Creek in Morgan and Athens counties, along many branches of Raccoon Creek in Gallia County, and along Leading Creek in Meigs County. Occasional pieces of wood may be found in the Allegheny and Pottsville series of Muskingum and Coshocton counties and in the Monongahela series near Beallsville in Monroe County. The silicified woods of Ohio are dense and heavy, nearly pure silica, but not highly colored. The material has been used in a small way for specimens and for cutting and polishing for ornaments and trinkets.

GANISTER

Ganister is, in the original sense, a dense clay-bonded sandstone, found under coal beds. It appears to have originated through secondary deposition of silica on the grains of quartz of very sandy clays. Such stone is associated with coal formation clays, ranges from 90 to 98 per cent silica, and frequently has the marks of *Lepidodendron* roots. Ganister has refractory properties of merit for special purposes. In Ohio such material is not abundant but is locally present in Lawrence, Scioto, Jackson, Vinton, and Hocking counties. It occurs most commonly on the horizon of the Clarion and the Sciotoville clays.

In this State the first application of ganister for useful purposes appears to have been for the lining of Lagrange furnace built in Lawrence County in 1836. It gave service also for refractory purposes in other blast furnaces of the area and in puddling furnaces at the rolling mills and cupolas of the foundries. With the introduction of the Bessemer process of steel making, ganister mixed with plastic clay was used regularly for lining and repairing converters. At present it finds application only in a desultory way.

PAINT PIGMENTS

In Ohio the production of paint pigments from the local rocks has been practiced since pioneer days but has never become an industry of importance. During the days of the charcoal furnaces in the Hanging Rock district, a special type of limonite ore, occurring most largely with the Ferriferous member as filling of joints and cavities of the Vanport limestone, was saved by the miners for shipment as paint pigment. The Separatists at Zoar ground pigments for their own use and for the general trade. Calcined ores appear to have been the base of the supply. Dark carbonaceous shale, fine-textured coal formation clay, light-colored limestone, and silica ground to rock flour have been used to some extent either along or blended with other substances.

WATER

Water, a true mineral when taken in the broader sense, is of the highest importance to man and is certainly one of the least expensive. Owing to the generosity of nature in giving to Ohio 37.97 inches of rainfall on the average per annum, to the thick mantle of drift, that acts as a sponge, over one-half or more of the State to porous strata, Ohio is particularly favored with sufficient water to support man with his varied wants, the animal life of the fields, and the plant life from diminutive forms to great trees. This heritage, if properly conserved and used, is of immense value.

Water in another form, that from mineral springs, has been a source of some revenue to Ohio through its direct sale for medicinal or simple drinking purposes and through the springs often being attractive locations for health and summer resorts. A mineral spring may be defined as one whose water is particularly charged with some mineral salt derived through solution from the rock formations. Such waters may be divided into several classes, depending mainly on the chief component held in solution.

In Ohio the most prominent class is carbonate water in which soluble calcium carbonate is the predominating substance. The most noted spring of this kind in the State is the famous "Blue Hole" near Castalia in Erie County. Many others of more or less importance are present throughout parts of western Ohio. Sulphide water with hydrogen sulphide as the special odoriferous agent is common throughout the belt of Ohio shale. The springs at Ohio Wesleyan University and those at Magnetic Springs in Delaware and Union counties respectively are representative examples. Chalybeate or iron-bearing water has soluble ferrous carbonate as the conspicuous components. Probably the outstanding spring of this kind is that at Yellow Springs in Greene County, where a large deposit of limonite

ore has been built up through contributions from the issuing waters. Sulphate water is one with mixed sulphate salts as the chief chemical. Such springs are not common in the State. The ones of most common reference are at Stryker in Williams County and at Green Spring in Sandusky. Water relatively pure issues from some of the thick sandstones throughout central and eastern Ohio and frequently is bottled and sold for drinking purposes.

The mineral waters of Ohio thus contribute in a small way to the wealth of the State and to places for health and enjoyment.

CONCLUSIONS

Thus Ohio is rich in the common rocks and minerals needed for economic progress. Advances in civilization require greater quantities of natural materials, a far wider range of products, and a more careful adjustment as to quality. Ohio has the common mineral resources both in quantity and in quality and has facilities for their manufacture and marketing. The rocks and minerals now form the basis for thousands of mining operations and for huge and varied industries involving millions of dollars of capital. The high development of the State is due in large measure to the abundance of its minerals and to their intelligent employment for many purposes.

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